The role of statistical and structural texture analysis in VHR image analysis for forest applications. A case study on Quickbird data in the Niepolomice Forest

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Abstract

Textural indices have the potential to measure and monitor canopy structures at landscape scales (after Blaschke, 2003). For forest this is related to monitoring on a multi-scale level. Due to recent improvements in hard and software, it has become easier to deal with textural characteristics of forest cover within the image domain. This allows combining classical theories on statistical textural measures (Haralick features) with structural textural measurements (Musick & Grover, 1990, Baatz & Schaepe, 2000). Transferability of textural features refers to characteristics of optical data in large mosaic used in seamless data as well as time series over the same area (change detection). Within the forest mask more detailed analysis has been applied. The typical 'forest peak' encountered in the IDM/Intensity scatterplot can be allocated in regular optical satellite data (Schleicher et. al, 2003). For analysed Quickbird data, the sequence of Homogeneity in this 'forest peak' for the red band is shown to be related to development (st)age in the (broadleaved) forest-stands. Aging forest become less homogeneous in the red-band. Therefore stand development can be modeled and predicted. Furthermore anomaly detection of forest changes comes within reach. This model is expected to be transferable through scale, area and time.

1 Forest Signature

The forest canopy can be regarded as a set of (expressed) propagules in an architectural system, which is optimizing for sunlight-interception. Reaching homogeneous canopy cover (closure) is a natural tendency within the forest stand. For establishing the relationship between the image domain and the ecological features, the textural measurements are confronted with ground truth. Homogenity of the canopy depends mainly on: tree-species, development phase, crown density and species-composition as well as disturbances of the classical 'lens-shape' of the forest-ecotope. High homogenity within stands result from the combination of those factors and additional information would pinpoint the main factor. Besides the role in the classification of forest stand, image-texture measurement can be used to define the relative (histogram) position towards similar stands of the same type and allows to express a ranking among their peers. This can be transferred to multi-temporal observations allowing a 'refined expression' of forest cover modification and a 'strong expression' in case of forest covers conversions. The objects of interest are related to the differentiation of 'Age' (Stand Development Stage). The life cycles of trees are diverse and depending on species. For example, a 50 year poplar stand compared to the

oak stand of the same age, already express senility, where oak stands show denser canopy and fierce competition for light. In this case poplar are almost on the end of the cycle and the oak just in their first quarter.
Within the case study the effect of statistical and structural texture measurements are calculated for original input data (Quickbird, optical bands) as well as for derivatives (NDVI). The role of texture in classifying and ranking forest stands is clarified. Considering the amount of 'ground truth' based on forest inventory, the link to biological/physical relationship between image and forest canopy is explained as best as possible.

2 Test site

The Niepolomice Forest (south Poland) is a remnant of the great primeval forest lowland that in the past covered the entire Vistula river. This forest area, located only 25 km to the East from the center of Cracow (fig.1), was always royal property and thus has been relatively well preserved.

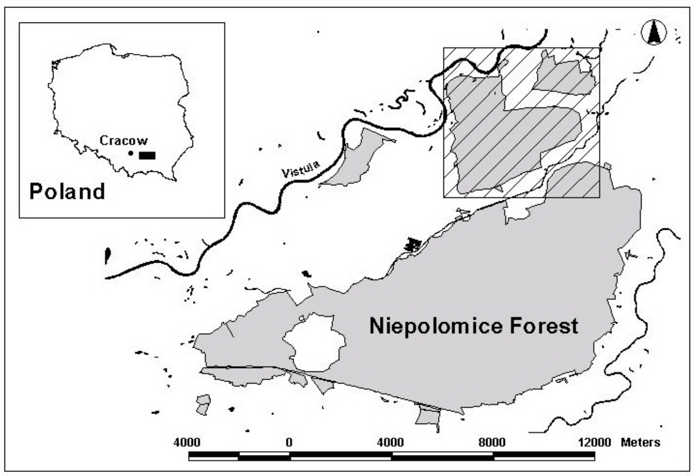

Figure 1: Test site in the Niepolomice Forest by Cracow (south Poland)

Today the forest complex areas, totally of 10.512 ha, are composed of two main forest parts, so called: "southern complex" (about 8.500 ha) - mainly composed of coniferous and mixed forest (Pino-Quercetum) and "northern complex" (about 1.850 ha) dominated by natural deciduous forest stands (Tilio-Carpinetum). The northern part is confined to a flood plain terrace of the Vistula, and is characterized by high ground water levels. This habitat condition reflects in the occurrence of moist oak-hornbeam or alder and elm forest (Grodzinska, 1984). The test site (ca. 1.575 ha) was chosen from the "northern complex" dominated by the oak (Quercus robur and Q. petrea 84,4%), black alder (Alnus glutinosa – 7,6%), ash (Fraxinus excelsior – 5,5%) and others deciduous tree species (beech, hornbeam - 2,5%). The average age of the forest stand in the test site is 84 years with the mean DBH of ca. 39 cm. The Quickbird (Digital Globe) image acquisition date was 15.09.2003 (10:35 EMT).

3 On Structure, Texture and Scale

Within the object oriented (OO) environment a sequence of Haralick statistical textures as well as structural textures, can be defined between three levels; the object primitive, the objects of interest and the final scale of forest GIS polygons. The role of different texture indices is related to the classification scales. In a hierarchical sequence of segmentation and classification, the textural measurements are adapted to the role and various levels of the analysis process. For the forest compartment the typical sequence is demonstrated and the textural features of image primitive, object of interest and final forest polygons are explained.

Patch analysis within forestry starts from a minimal area defined by the capability of a manageable forest compartment (ca. 0.5 Ha) where the architecture of tree-crown-mosaics follows a manipulated uniform ‘treatment unit’. From the image in the 0,6 meter pixel resolution this requires object primitives of around 100m² to 200 m² and objects of interest from 0,5 to 2,0 Ha. In this case the ‘manageable forest compartment’ is a different unit than pure natural patches as they appear in stages of canopy development. Although both units have their typical spatial distributions, the differences are compared for statistical textures as well as structural textural behavior. The aim is the selection of a textural attribute-set that allows automatic change detection and is stable and transferable to others satellite data.

4 Considering pre-processing

Earlier studies on forest classification showed the differentiation of forest cover for more detailed stand information using the standard deviation for the various spectral bands (Burger & Steinwender, 1996, de Kok et. al., 2000). The standard deviation in VHR data is quite important for the first hierarchical level of classification, it is the forest mask. Further differentiations on lower hierarchical levels have to rely on more advanced techniques related to variance per segment (de Kok, 2004). More detailed studies on LANDSAT data have revealed the importance of textural and structural parameters for forest classification (Burger & Steinewender, 1996). Based upon the availability of advanced hardware and software (eCognition) as well as the excellent quality of VHR satellite data, it has become necessary to evaluate those ideas on the transferability of these parameters from classical LANDSAT information towards VHR datasets (QuickBird).

5 Methods

The general size of the object primitive is a cluster of young stands and/or large individual crowns, which lead to segment sizes of 300 to 500 pixels of ca. 100 to 200 m^2 (0,62 meter pixel). With this size, the various segments are representative for their group of forest age classes which in this particular case are areas size of ca. 0.01 Ha.

In this study, the statistical textural parameter Homogenity (also known as IDM, after Steinnocher, 1997) is chosen as well as the feature 'mean difference to neighbor' which is a stand-in for the 'structural texture' part. The use of the structural part is limited and pre-defined by the simple 'area factor' of selected average size of the object primitive. Note here the importance of bypassing the traditional filter based technique (in eCognition) for statistical texture calculation, as the moving window technique has been a bottleneck for texture analysis over a decade in remote sensing. Nevertheless, the structural texture features are limitedly used for separating of old crowns from shadow and younger stands before classification based segmentation in a 4 levels iterative sequence. The final output are polygons (*.shp) with similar age units within the compartment. The single polygon (SILP database) contains an age value representing the whole stand. The sub-objects of interest with the largest area occupation within the stand contain values for IDM in red, NIR and the panchromatic band. These IDM values are considered to correspondent with the overall forest GIS age value per stand. All object primitives are weighted according to their size and all objects of interest contribute to the output value of IDM per stand.

For Hierarchical classification, the chosen sequence follows a top down approach:

(1)Forest Mask—(2)Coniferous/Broadleaved—(3)Development Age – (4-*Species*).

This study shows a part from ongoing research and is limited to the focus of the relationship of textural and structural parameters for the Development-Age per stand in broadleaved forest. In this particular case study, species composition in broadleaved areas is as information incorporated in the well-maintained SILP database. Also the initiation date (planting) is recorded, however, age in years and the Development-Stage or Development Age can differ, the latter being the focus of testing textural differences. Age classes with a 0.01 Hectare minimum are showing how far the complete stand is following expected development. Central focus of measurement has become the homogeneity (IDM) in the red channel which has shown already it's particular behavior for forest stands (Schleicher et. al, 2003, de Kok 2004).

6 Results

The initial investigation shows a high detailed segmentation of individual crowns only on a 2000*2000 pixel subset, with an average object size of 13 m^2. Here the IDM factor for red band is responding with lower values for the crown area of older trees in the scatterplot (fig. 2A). This visualization induces a need for further analysis of this behavior. Therefore a more detailed test is applied on the overall broadleaved stands. In this next step, the dominant crown area per broadleaved stand is segmented for the larger 10728x12568 pixels scene. Figure 2B visualizes the diminishing of the IDM values (for the red band) with stand-age. Here the OO-primitives have an average sizes of 190 m^2. For the classical forest peak, figure 2B visualizes that the top of the peak is occupied by the younger forest (the dotted line in fig. 2B is added for clarification in black & white print).

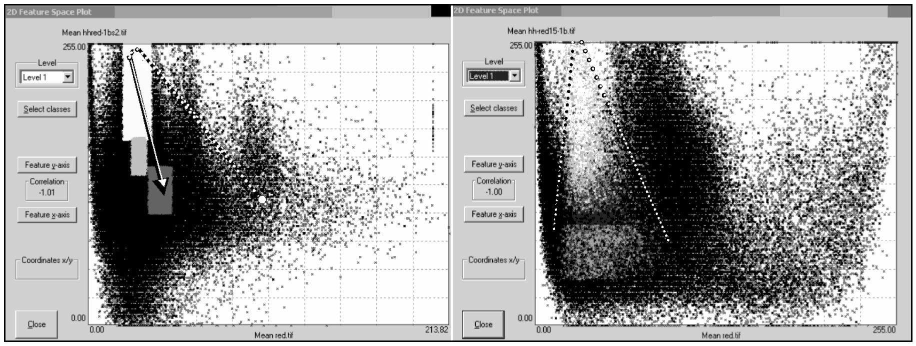

Figure 2.A & 2 B: Scatterplots of IDM vs. Red band of Quickbird

From the visualization to modeling, a linear regression was applied based upon the statistic shown in figure 2B. The initial model and the correlation results are shown in figure 3 and 4. Remark that the normal shadow component cast by the older crown on it's neighborhood would suggest, that older forest appear more homogenous in the red part of the spectrum than younger stands. However, at the various scales of segmentation, the older crowns show lower homogeneity values. The relationship between IDM and the infrared band is less correlated with age (see figure 4).

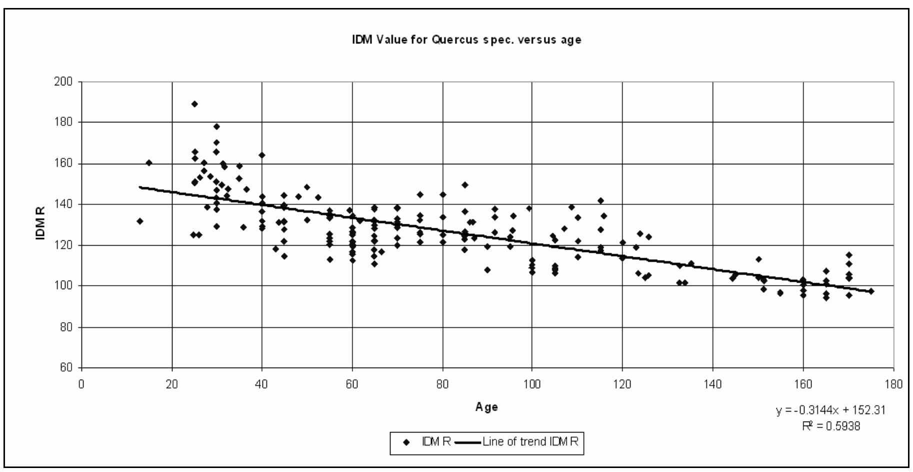

Figure 3. The linear regression IDM- Red and Age for *Quercus sp*. (R^2 =0.5939)

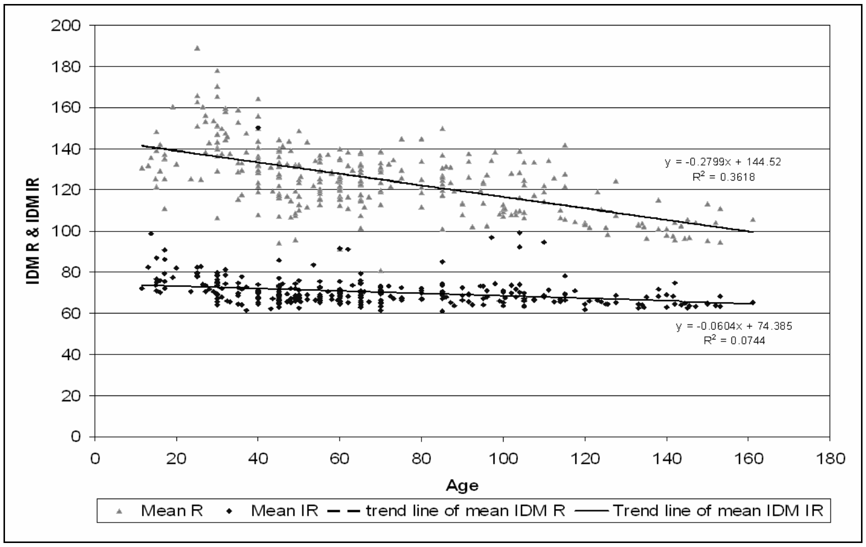

Figure 4. The linear regression between IDM- Red-Band and Age for all broadleaved species (R^2_{red} decreases to 0.3618).

7 Discussion

The relationship between low variance in the red band versus higher variance in the infrared band seems to be a factor related to development stage or age of broadleaved tree stands. For a single Quercus sp. the R^2 value shows the value 0,5983 compared to 0.3618 for all analysed broadleaved stands. This suggests that the linear model dependents on tree species. The typical behavior of IDM was already encountered in LANDSAT 7 data but not explained (de Kok, 2004). However age is related to tree-height and shadow, so for differentiation of LANDSAT imagery, the role of shadow on the variance red/infrared inside a single LANDSAT pixel was unclear. The details in Quickbird image make it possible to separate shadows from individual trees and evaluate the IDM factor for the crown areas only. The shape of the scatterogram and the positions: the younger stands in the top and the older stands under the top show a gradient sequence makes forest change detection possible for qualitative analysis. The dotted line in figure 2A shows the expected path of development from a *non-forest* plot through *young forest* towards *old forest.* As the aging forest on the same area become less homogeneous in the red-band, the future development per stand can be modeled. Now various anomaly detections for forest change come within reach, transferable through mapping scale, area and time. The three factors: species, height and age, are crucial parameters in any forest assessment. They are used to evaluate biomass, yield, ecological status etc. Species information can be derived from existing forest inventory data and this factor remains quite stable over decades.

Nevertheless, species identification in VHR data is progressing. Cheaper seamless details on height information are becoming rapidly within reach, as radar imagery on worldwide scale are available like the SRTM mission results. Age and development stage can be assessed by texture analysis. Thus making an overall cross validation between large area data and forest GIS more complete.

8 Conclusions

The classification of forest areas has to be related to general biophysical parameters. VHR data delivers the explanation of spectral signature characteristic for forests. Explaining the development stage of tree stands from texture, immanently incorporates the development model for tree stands as well as transferability of this characteristic attribute in optical data in a similar way like NDVI. In Pan-European perspective the issue of the transferability of the change of signal used for forest monitoring, which can be applied through the scales from very fine to coarse resolutions, has not lost it's importance (after Häusler & Deshayes, 1996). The study can be regarded as an iterative step towards this goal. The VHR data allows an explanation of the difference in variance of the red band. This is not only caused by the shadow component in older forest stands, but the older crowns become less homogeneous. This brings us back to the evaluation of the same parameters within the LANDSAT 7 data, for which the factor was not only crucial for the creation of the forest mask, but within the stand, the development stage can be assessed.

9 Outlook

For large area data and European wide applications, the texture and structural factors of forest should be combined with forest-height (from RADAR) and species. Moreover the price of forest parameter extraction should reach the level of 0,02 Euro/km^2.

At this moment an alternative sensor for LANDSAT 7 and the distribution of cheap radar DEM information has priority. The basic classes for the forest mask, coniferous versus broadleaved on a European scale is solved. Development stage of forest becomes achievable when height information and variance-homogeneity (red/infrared bands) are combined in data fusion analysis. Such standard procedures allow change detection monitoring over the enlarged EU and PHARE members creating an effective decision support tool for the political and administrative level.

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